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IMPACT OF THE DISCRETE ADDRESS BEACON SYSTEM (DABS) ON AIR TRAF--ETC(U)

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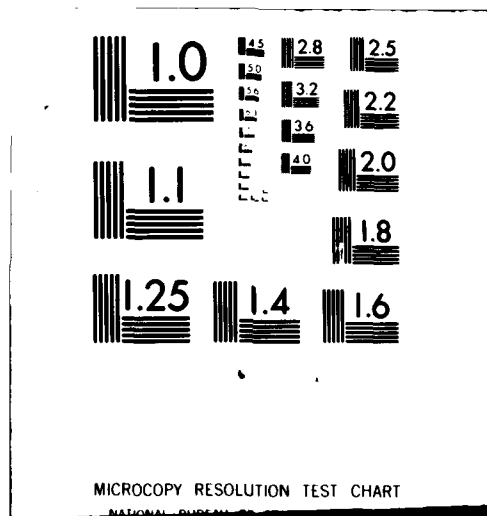
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**IMPACT OF THE
DISCRETE ADDRESS BEACON SYSTEM (DABS)
ON AIR TRAFFIC CONTROL RADAR BEACON SYSTEM
(ATCRBS) PERFORMANCE IN SELECTED DEPLOYMENTS.**

IIT Research Institute
Under Contract to
DEPARTMENT OF DEFENSE
Electromagnetic Compatibility Analysis Center
Annapolis, Maryland 21402

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G. Fleming



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| 16. Abstract A computer analysis was conducted to investigate the effect of the proposed Discrete Address Beacon System (DABS) on the Air Traffic Control Radar Beacon System (ATCRBS) in a future (1982) Los Angeles, CA, air traffic environment. The performance of ATCRBS was examined at two sites, both with a) the existing all-ATCRBS ground environment and b) a mixed ATCRBS/DABS ground environment (using various levels of DABS channel activity). It was observed that, in general, DABS operations will not affect the ability of ATCRBS interrogators to perform their air traffic control function of reliably detecting aircraft. | | | |
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ENGLISH/METRIC CONVERSION FACTORS

LENGTH

| To From | cm | m | km | in | ft | mi | nmi |
|------------|---------|--------|-----------------------|--------|--------|-----------------------|-----------------------|
| cm | 1 | 0.01 | 1x10 ⁻⁵ | 0.3937 | 0.0328 | 6.21x10 ⁻⁶ | 5.59x10 ⁻⁶ |
| m | 100 | 1 | 0.001 | 39.37 | 3.281 | 0.0006 | 0.0005 |
| km | 100,000 | 1000 | 1 | 39370 | 3281 | 0.6214 | 0.5395 |
| in | 2.540 | 0.0254 | 2.54x10 ⁻⁵ | 1 | 0.0833 | 1.58x10 ⁻⁵ | 1.37x10 ⁻⁵ |
| ft | 30.48 | 0.3048 | 3.05x10 ⁻⁴ | 12 | 1 | 1.69x10 ⁻⁴ | 1.64x10 ⁻⁴ |
| mi | 160,900 | 1609 | 1.609 | 63360 | 5280 | 1 | 0.8688 |
| nmi | 185,200 | 1852 | 1.852 | 72930 | 6076 | 1.151 | 1 |

AREA

| To From | cm ² | m ² | km ² | in ² | ft ² | mi ² | nmi ² |
|------------------|-----------------------|----------------------|------------------------|----------------------|----------------------|------------------------|------------------------|
| cm ² | 1 | 0.0001 | 1x10 ⁻¹⁰ | 0.1550 | 0.0011 | 3.86x10 ⁻¹¹ | 5.11x10 ⁻¹¹ |
| m ² | 10,000 | 1 | 1x10 ⁻⁶ | 1550 | 10.76 | 3.86x10 ⁻⁷ | 5.11x10 ⁻⁷ |
| km ² | 1x10 ¹⁰ | 1x10 ⁶ | 1 | 1.55x10 ⁹ | 1.08x10 ⁷ | 0.3861 | 0.2914 |
| in ² | 6.452 | 0.0006 | 6.45x10 ⁻¹⁰ | 1 | 0.0069 | 2.49x10 ⁻¹⁰ | 1.88x10 ⁻¹⁰ |
| ft ² | 929.0 | 0.0929 | 9.29x10 ⁻⁸ | 144 | 1 | 3.59x10 ⁻⁸ | 2.71x10 ⁻⁸ |
| mi ² | 2.59x10 ¹⁰ | 2.59x10 ⁶ | 2.590 | 4.01x10 ⁹ | 2.79x10 ⁷ | 1 | 0.7548 |
| nmi ² | 3.43x10 ¹⁰ | 3.43x10 ⁶ | 3.432 | 5.31x10 ⁹ | 3.70x10 ⁷ | 1.325 | 1 |

VOLUME

| To From | cm ³ | liter | m ³ | in ³ | ft ³ | yd ³ | fl. oz. | fl. pt. | fl. qt. | gal. |
|-----------------|-------------------|--------|-----------------------|-----------------|-----------------------|-----------------------|---------|---------|---------|--------|
| cm ³ | 1 | 0.001 | 1x10 ⁻⁶ | 0.0610 | 3.53x10 ⁻⁵ | 1.31x10 ⁻⁶ | 0.0338 | 0.0021 | 0.0010 | 0.0002 |
| liter | 1000 | 1 | 0.001 | 61.02 | 0.0353 | 0.0013 | 33.81 | 2.113 | 1.057 | 0.2642 |
| m ³ | 1x10 ⁶ | 1000 | 1 | 61,000 | 35.31 | 1.308 | 33,800 | 2113 | 1057 | 264.2 |
| in ³ | 16.39 | 0.0163 | 1.64x10 ⁻⁵ | 1 | 0.0006 | 2.14x10 ⁻⁵ | 0.5541 | 0.0346 | 2113 | 0.0043 |
| ft ³ | 28,300 | 28.32 | 0.0283 | 1728 | 1 | 0.0370 | 957.5 | 59.84 | 0.0173 | 7.481 |
| yd ³ | 765,000 | 764.5 | 0.7646 | 46700 | 27 | 1 | 25900 | 1616 | 807.9 | 202.0 |
| fl. oz. | 29.57 | 0.2957 | 2.96x10 ⁻⁵ | 1.805 | 0.0010 | 3.87x10 ⁻⁵ | 1 | 0.0625 | 0.0312 | 0.0078 |
| fl. pt. | 473.2 | 0.4732 | 0.0005 | 28.88 | 0.0167 | 0.0006 | 16 | 1 | 0.5000 | 0.1250 |
| fl. qt. | 948.4 | 0.9463 | 0.0009 | 57.75 | 0.0334 | 0.0012 | 32 | 2 | 1 | 0.2500 |
| gal. | 3785 | 3.785 | 0.0038 | 231.0 | 0.1337 | 0.0050 | 128 | 8 | 4 | 1 |

MASS

| To From | g | kg | oz | lb | ton |
|------------|---------|--------|--------|--------|-----------------------|
| g | 1 | 0.001 | 0.0353 | 0.0022 | 1.10x10 ⁻⁶ |
| kg | 1000 | 1 | 35.27 | 2.205 | 0.0011 |
| oz | 28.35 | 0.0283 | 1 | 0.0625 | 3.12x10 ⁻⁵ |
| lb | 453.6 | 0.4536 | 16 | 1 | 0.0005 |
| ton | 907,000 | 907.2 | 32,000 | 2000 | 1 |

TEMPERATURE

$$^{\circ}\text{C} = 5/9 (^{\circ}\text{F} - 32)$$

$$^{\circ}\text{F} = 9/5 (^{\circ}\text{C}) + 32$$

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This report has been reviewed and is approved for publication.

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FEDERAL AVIATION ADMINISTRATION
SYSTEMS RESEARCH AND DEVELOPMENT SERVICE
SPECTRUM MANAGEMENT BRANCH

STATEMENT OF MISSION

The mission of the Spectrum Management Branch is to assist the Department of State, National Telecommunications and Information Administration, and the Federal Communications Commission in assuring the FAA's and the nation's aviation interests with sufficient protected electromagnetic telecommunications resources throughout the world and to provide for the safe conduct of aeronautical flight by fostering effective and efficient use of a natural resource - the electromagnetic radio frequency spectrum.

This objective is achieved through the following services:

- . Planning and defending the acquisition and retention of sufficient radio frequency spectrum to support the aeronautical interests of the nation, at home and abroad, and spectrum standardization for the world's aviation community.
- . Providing research, analysis, engineering, and evaluation in the development of spectrum related policy, planning, standards, criteria, measurement equipment, and measurement techniques.
- . Conducting electromagnetic compatibility analyses to determine intra/ intersystem viability and design parameters, to assure certification of adequate spectrum to support system operational use and projected growth patterns, to defend aeronautical services spectrum from encroachment by others, and to provide for the efficient use of the aeronautical spectrum.
- . Developing automated frequency selection computer programs/routines to provide frequency planning, frequency assignment, and spectrum analysis capabilities in the spectrum supporting the National Airspace System.
- . Providing spectrum management consultation, assistance, and guidance to all aviation interests, users, and providers of equipment and services, both national and international.

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SECTION 1

INTRODUCTION

BACKGROUND

The Discrete Address Beacon System (DABS) is an evolutionary upgrading of the Air Traffic Control Radar Beacon System (ATCRBS). It is intended to operate compatibly with and eventually replace ATCRBS in the performance of Air Traffic Control (ATC) surveillance and data acquisition functions. DABS is to be gradually phased in during the 1980's as part of the Federal Aviation Administration (FAA) ATC System.

ATCRBS is presently used by the FAA as the primary means of surveillance for ATC. The multiple response characteristic of ATCRBS gives rise to an excessive number of unwanted replies in dense regions of cooperating aircraft (A/C). In addition, overlapping replies from closely spaced A/C (synchronous garble) occur in these dense A/C environments. Given the projected increase in transponder-equipped A/C, the intrasystem interference experienced can be expected to increase.

The use of a selective address ATC system is designed to alleviate these problems. The capability to selectively interrogate DABS-equipped A/C, coupled with limited interrogations of ATCRBS-equipped A/C (enabled by monopulse) will result in a reduction of the total number of transmitted interrogations and, consequently, in the fruit rate at the ground system. Also, this method will not elicit overlapping responses from closely spaced A/C because a DABS reply will only be generated by the A/C to which the interrogation is addressed.

Prior to full deployment of DABS there will be an intervening period in which both systems will be operational. Consequently, the FAA tasked ECAC to investigate the impact of DABS operation on ATCRBS performance for such a period.

OBJECTIVE

The objective of this analysis was to determine the relative performance of the ATCRBS in environments that include various levels of DABS surveillance and data-link communications.

APPROACH

This analysis was conducted as a simulation, making use of the DABS/ATCRBS/AIMS^a Performance Prediction Model, which was developed by ECAC. This is a very detailed simulation model that includes known locations of existing ATCRBS interrogators. Each interrogator is represented by a directional antenna that rotates as a function of time. The rotation rate of this antenna, as well as its gain and beamwidth, and a number of interrogator characteristics such as transmitter power and receiver sensitivity are all assigned in the model to match the known characteristics of that particular real interrogator. It is also possible to add to the model hypothetical interrogators, invented for the purpose of investigating future conditions, or for assessing new systems such as DABS.

The DABS/ATCRBS/AIMS Performance Prediction Model includes subroutines that are used to represent a DABS sensor in detail. Adaptive reinterrogation is included, as are the scheduling algorithms that accomplish surveillance and data link functions including Extended Length Message protocol. A more detailed description of the model is given in Reference 1.

¹Crawford, C. R., and Ehler, C. W., *The DABS/ATCRBS/AIMS Performance Prediction Model*, FAA/RD-79-088, ECAC-PR-77-061, Annapolis, MD, November, 1979.

^aAIMS - ATCRBS IFF Mark XII System.

Section 1

The advantage in this detailed approach is the opportunity it affords to discover possible interference problems that could result from detailed time peaking or spatial peaking. Time peaking conditions (such as the simultaneous illumination of a region of airspace by two or more mainbeams) and spatial peaking conditions (such as above-average density of air traffic in certain areas) are both included in the model, so any adverse results of these peaks will appear in the analysis results. Scenarios were adapted to assess the performance of the ATCRBS/MARK X ground systems at Los Alamitos Naval Air Station and at the Long Beach FAA site. For each site, the performance of ATCRBS was predicted both with and without DABS operations. The air traffic environment consisted of the standard Los Angeles traffic model (the 1982 model).²

Two ground environments were modeled, both of which were obtained from ATCRBS/IFF files at ECAC. The first consisted of all interrogators within a 500 nmi radius of Los Angeles, CA as requested by FAA. The second was identical to the first with the exception that four specified FAA site interrogators were converted to DABS sensors.

Performance of all transponders within range of the interrogator-of-interest (I_o) was assessed in terms of the suppression rate, interrogation rate, and reply probability. The performance of the ATCRBS ground system was evaluated in terms of the ATCRBS fruit rate, DABS fruit rate, and the detector output of the I_o . It should be emphasized that all system parameters are secondary in importance to the ability of the ground system to perform its fundamental air traffic control function of reliably detecting A/C.

² Hildenberger, Mark, *User's Manual for the Los Angeles Basis Standard Traffic Model*, (Card Deck/Character Tape Version), FAA-RD-73-89, FAA, May 1973, (U).

SECTION 2
MODEL INPUTS

INTERROGATOR-OF-INTEREST OPERATION

To determine the effect of DABS on ATRBS, the ground system performance with and without DABS was simulated for both the Los Alamitos ATRBS-Mark X and the Long Beach ATRBS interrogators. The characteristics of the interrogators at Los Alamitos and Long Beach, as modeled, are given in TABLES 1 and 2, respectively.

The Long Beach interrogator was assumed to utilize an ARTS III processor. The interrogator's performance was based on the ability of the processor to detect targets and to validate Mode A (identity) and Mode C (altitude) reply codes. Detection required receiving 5 clear replies from 21 interrogations. Validation required receiving two consecutive clear replies to interrogations of the same mode. DABS fruit that overlapped elicited replies was assumed to garble the desired replies to the extent that they could not be properly decoded.

The Los Alamitos ATRBS-Mark X interrogator does not have automatic target detection capability. Its output consists simply of a pulsed video response triggered by the detection of a bracket pair. Its performance was based on the ability to decode desired bracket pairs in the presence of fruit. DABS fruit that overlapped elicited replies was assumed to inhibit detection of bracket pairs. In addition, DABS fruit was assumed to initiate false bracket decodes and thus, spurious video responses.

EQUIPMENT DEPLOYMENT

Ground Interrogator Environment

Two ground environments were modeled, both of which were taken from ECAC's IFF files. The first consisted of the 141 interrogators within a 500 nmi radius

TABLE 1

PARAMETER ASSIGNMENTS
IN THE LOS ALAMITOS SCENARIOSINTERROGATOR CHARACTERISTICS

| | |
|----------------------|---|
| LATITUDE | 33° 47' 17" N |
| LONGITUDE | 118° 03' 04" W |
| POWER | 0.08 kW |
| RECEIVER SENSITIVITY | -81 dBm |
| STC | 40 dB @ 1 nmi |
| SCAN RATE | 20 RPM |
| INTERROGATION RATE | 300/s |
| MODE INTERLACE | A, A |
| SLS TYPE | None |
| RECEIVER RANGE | 40 nmi |
| INTERROGATOR TYPE | AN/UPX-6 |
| CABLING LOSS | 4 dB |
| ANTENNA | 17 dBi for 3.5° -5 dBi for 56° -12 dBi for 300.5° |

TRANSPONDER CHARACTERISTICS

| | |
|--------------|----------|
| POWER | 0.5 kW |
| SENSITIVITY | -77 dBm |
| CABLING LOSS | 3 dB |
| ANTENNA | -2.5 dBi |

TABLE 2
PARAMETER ASSIGNMENTS IN THE
LONG BEACH SCENARIOS

INTERROGATOR CHARACTERISTICS

| | |
|----------------------|---|
| LATITUDE | 33° 49' 09" N |
| LONGITUDE | 118° 08' 16" W |
| POWER | 0.08 kW |
| RECEIVER SENSITIVITY | -86 dBm |
| STC | 40 dB @ 1 nmi |
| SCAN RATE | 13 RPM |
| INTERROGATION RATE | 415/s |
| MODE INTERLACE | A,A,C |
| SLS TYPE | IMPROVED |
| RECEIVER RANGE | 60 nmi |
| INTERROGATOR TYPE | ATCBI-0003D |
| CABLING LOSS | 4 dB |
| ANTENNA | 21 dBi for 4° -7 dBi for 56° -19 dBi for 300° |

TRANSPONDER CHARACTERISTICS

| | |
|--------------|----------|
| POWER | 0.5 kW |
| SENSITIVITY | -77 dBm |
| CABLING LOSS | 3 dB |
| ANTENNA | -2.5 dBi |

of Los Angeles, CA. The second was identical to the first with the exception that four specified FAA site interrogators were converted to DABS Sensors.

DABS Sensor Deployment. For the Los Alamitos DABS scenarios, the four FAA sites converted to DABS sensors were Los Angeles (LAX-4), Burbank, Long Beach, and Ontario. Their surveillance and data-link coverage zones are specified in TABLE 3 and illustrated in Figure 1.

For the Long Beach DABS scenario, the four DABS sensors were Los Angeles (LAX-4), Burbank, Ontario, and El Toro. Their surveillance and data-link responsibilities are specified in TABLE 4 and illustrated in Figure 2.

DABS Network Operation. Each of the four DABS sensors maintained both surveillance and data-link communication with the aircraft within its primary zone of responsibility.^a In addition, each DABS sensor maintained surveillance coverage of aircraft within a neighboring (or secondary) zone, so that dual sensor coverage was provided throughout. The process of DABS target acquisition, using ATCRBS/DABS all-calls, was modeled by having 20% of all DABS aircraft (randomly selected) reply to all-calls and the remaining 80% locked out. Acquisition of these targets is accomplished by the DABS network management functions. DABS data-link services are represented by three different scenarios. Taking these together with an ATCRBS-only scenario gives a family of four scenarios of different levels of DABS activity ranging from zero to a very high level.

Scenario 1, ATCRBS Baseline. Reference case to which the other cases can be compared.

Scenario 2, DABS Surveillance. Dual DABS surveillance of all airspace. No data-link services.

^aThis zone was bounded by the perpendicular bisector of the segment joining the DABS sensor with any other DABS sensor. Every point in the DABS sensor's zone has the property of being closer to that sensor than to any other DABS sensor.

Section 2

Scenario 3, DABS Surveillance Plus Data-Link Without Cockpit Display of Traffic Information. All DABS sensors are equipped to provide ATC data, Automatic Traffic Advisory and Resolution Service (including Pilot Warning Indicator), weather and navigation services.

Scenario 4, DABS Surveillance Plus Data-Link With CDTI. All DABS sensors are equipped to provide CDTI in addition to all of the services of Scenario 3.

Cockpit Display of Traffic Information (CDTI) has been separated out because it is thought to constitute a dominating data link load; and its design is uncertain at this time. The CDTI service is modeled as having two options available to each aircraft: a "medium option" that provides the aircraft with reports on an average of 3 and a maximum of 6 nearby aircraft, and a "high option" that provides an average and maximum of about 5 and 15 aircraft, respectively.

The model for simulating these data link scenarios is given in APPENDIX A. DABS data-link and surveillance signal formats and DABS protocol are described in Reference 1. (See the DABS National Standard³ for a more comprehensive discussion of DABS protocol.)

TABLE 3
DABS SENSOR SURVEILLANCE AND DATA-LINK ZONE ASSIGNMENTS
FOR LOS ALAMITOS SCENARIOS (See Figure 1)

| Site | Surveillance Responsibility | | Data-Link Responsibility |
|------------------------|-----------------------------|-----------|--------------------------|
| | Primary | Secondary | |
| Burbank | A | D | A |
| Los Angeles (LAX-4) | B | A | B |
| Long Beach | C | B | C |
| Ontario | D | C | D |

³The proposed U.S. National Aviation Standard for the Discrete Address Beacon System, March 1978.

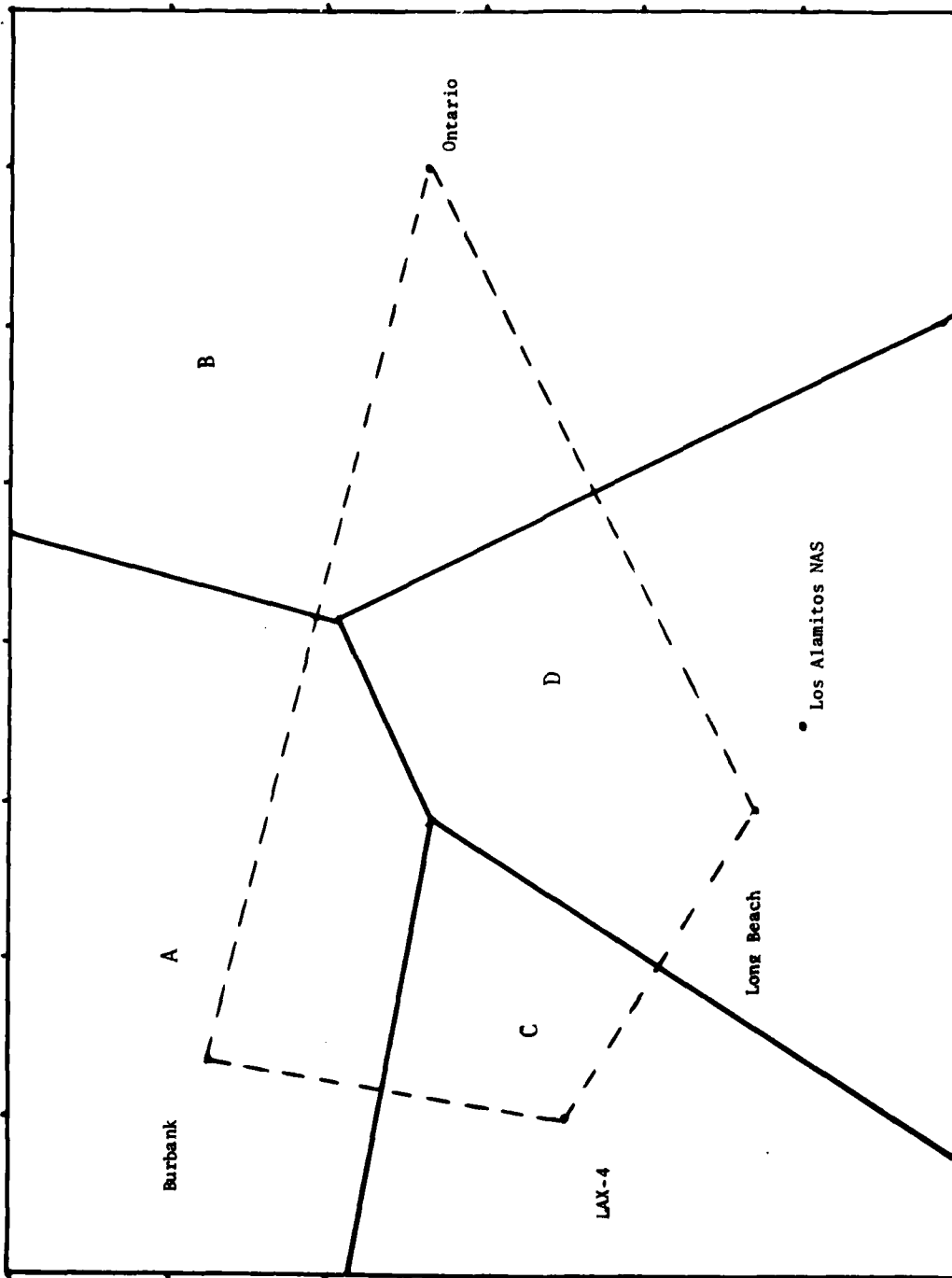


Figure 1. DABS sensor configuration for Los Alamitos scenarios (see TABLE 3).

TABLE 4

DABS SENSOR SURVEILLANCE AND DATA-LINK ZONE ASSIGNMENTS
FOR LONG BEACH SCENARIOS (See Figure 2)

| SITE | SURVEILLANCE RESPONSIBILITY | | DATA-LINK RESPONSIBILITY |
|------------------------|-----------------------------|-----------|--------------------------|
| | Primary | Secondary | |
| Burbank | A | B | A |
| Los Angeles (LAX-4) | B | C | B |
| El Toro | C | D | C |
| Ontario | D | A | D |

Air Traffic Environment

The air traffic environment analyzed was modeled by using the standard LA high density traffic model. It consists of 743 aircraft; 689 of the aircraft are designated general aviation, 30 are air carrier, and 24 are military. Fifty-three of the general aviation aircraft are "high performance" (multi-engine aircraft). Figure 3 illustrates this deployment as seen by Los Alamitos NAS. Figure 4 shows the same deployment as seen by the interrogator at Long Beach. The DABS sensors and their primary zones are also overlayed on Figures 3 and 4. In the cases simulated, all of these aircraft were equipped with DABS transponders. This is thought to be a worst case (when compared to cases involving some of the aircraft being ATCRBS equipped) because: (1) the DABS interrogation environment increases according to the number of DABS targets, (2) the DABS reply environment increases according to the number of DABS targets and (3) a DABS transponder reacts to an ATCRBS/DABS all-call interrogation with a DABS reply which constitutes more deadtime.

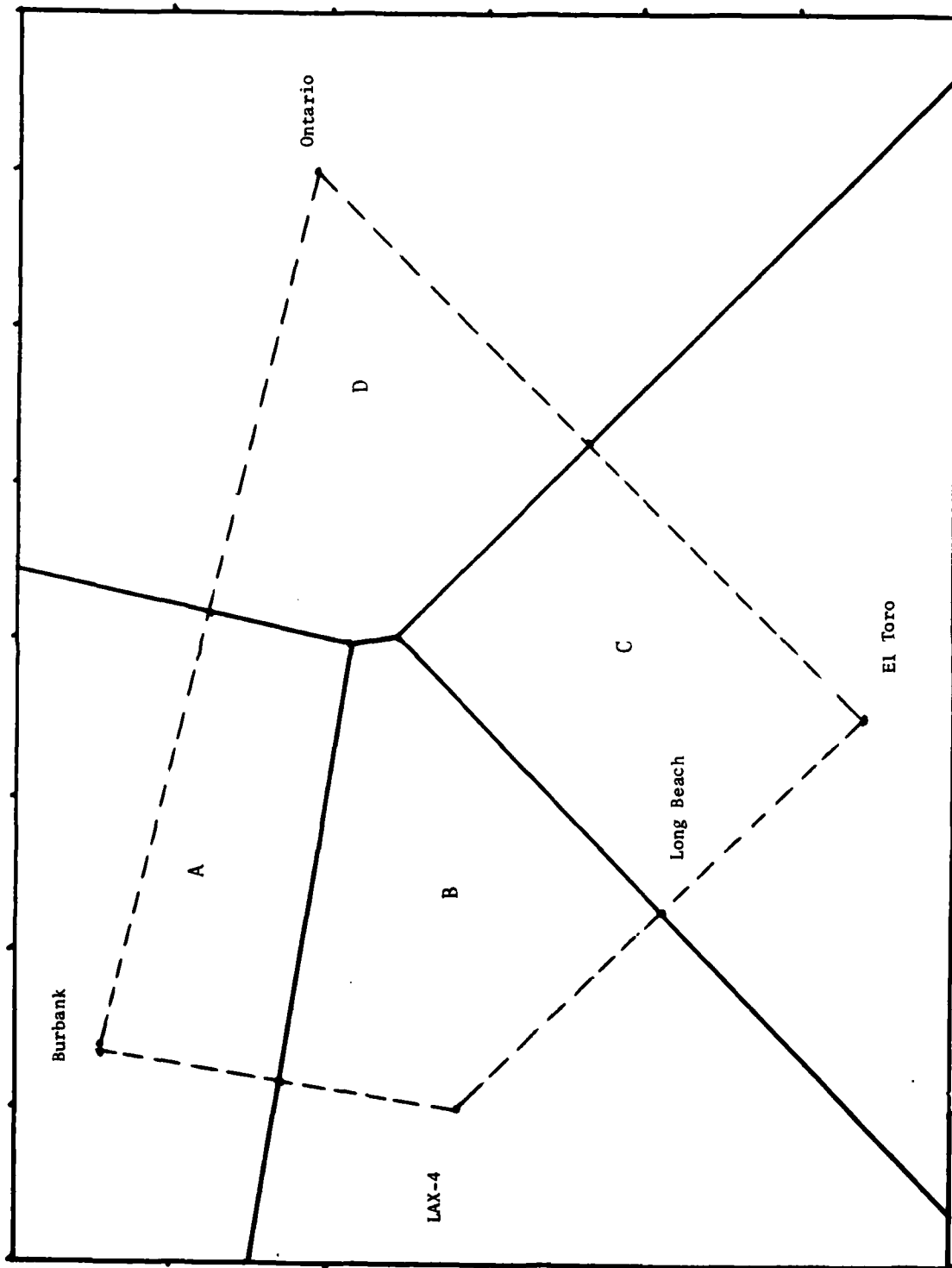


Figure 2. DABS sensor configuration for Long Beach scenarios.
(See TABLE 4)

Section 2

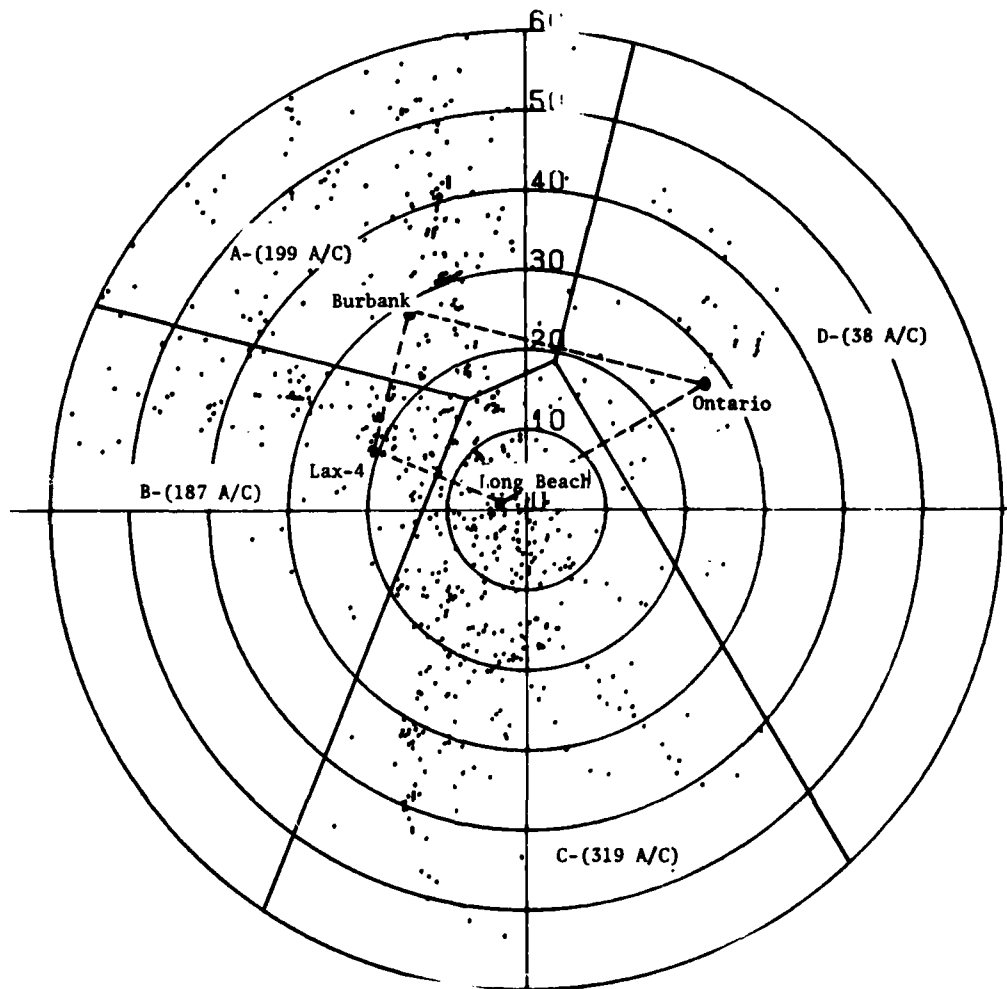


Figure 3. Transponder deployment as seen from Los Alamitos NAS ($33^{\circ} 47' 17''$ N, $118^{\circ} 03' 57''$ W).

Section 2

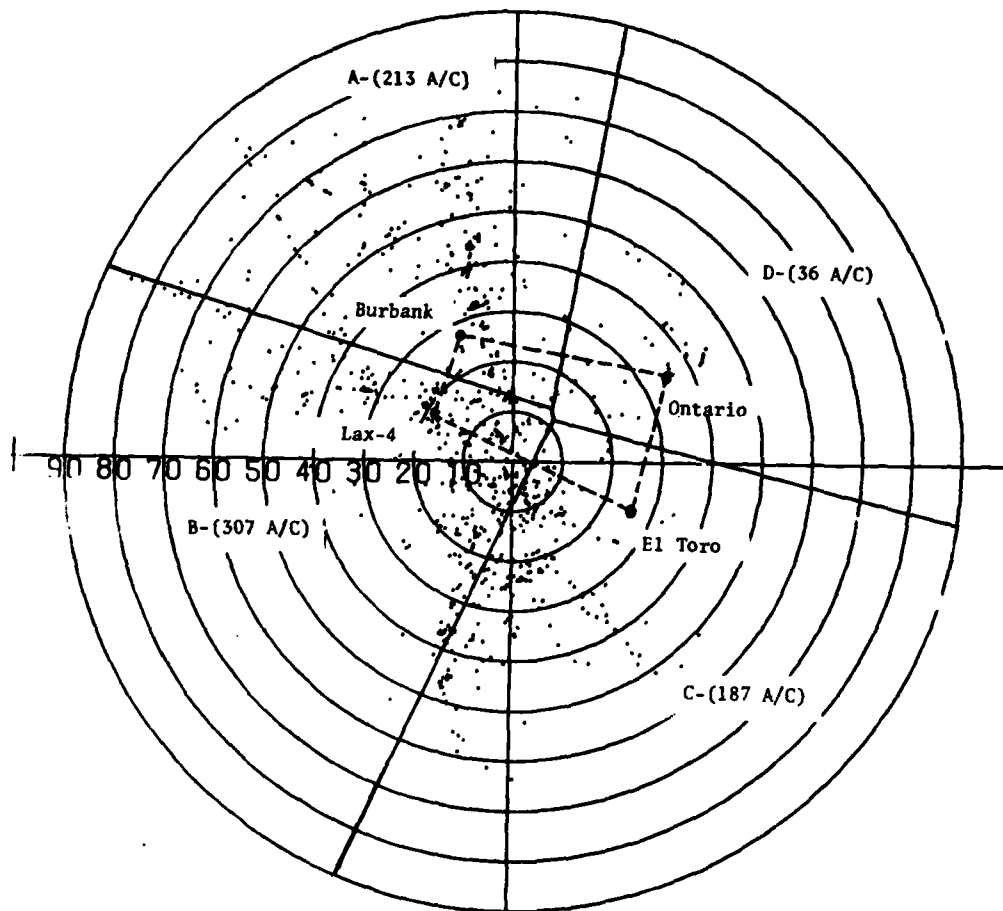


Figure 4. Transponder deployment as seen from Long Beach ($33^{\circ} 49' 09''$ N, $118^{\circ} 08' 16''$ W).

UPLINK SIGNAL ENVIRONMENTLos Alamitos Simulations

Four Scenarios were developed to evaluate the impact of DABS on ATCRBS-Mark X operation at Los Alamitos NAS. The baseline simulation (Scenario 1) was used to examine Los Alamitos performance using the existing ATCRBS ground environment. Scenarios 2, 3, and 4 utilized the mixed DABS/ATCRBS ground environment.

Scenario 2 restricted the DABS sensors to "surveillance only" coverage. (See APPENDIX A for detailed descriptions of the various data-link services.)

For Scenario 3, the air carrier and high-performance general aviation aircraft were combined into a group that received extended length data-link service and surveillance service from their primary sensors. The remaining 660 A/C received normal data-link service and surveillance service from their primary sensors. Each A/C received one surveillance interrogation per scan from its secondary sensor.

Scenarios 2 and 3 were used to examine a "worst-case" situation in which it was assumed that the DABS sensor at Burbank had failed. Burbank's surveillance responsibilities were assumed by the sensors at Long Beach and Ontario; Los Angeles (LAX-4) assumed Burbank's data-link services. TABLE 5 summarizes these modified zones of responsibility.

The remaining Los Alamitos scenario (4) was used to examine the ATCRBS-Mark X performance with just two DABS sensors - Los Angeles (LAX-4) and Ontario. (Burbank and Long Beach were reverted to ATCRBS interrogators.) The surveillance and data-link services were identical to those described in Scenario 3. The zone assignments are listed in TABLE 6.

Section 2

TABLE 5

MODIFIED DABS SENSOR SURVEILLANCE AND DATA-LINK ZONE
ASSIGNMENTS FOR LOS ALAMITOS ANALYSIS WITH BURBANK INOPERATIVE
(Scenarios 2 & 3; See Figure 1)

| SITE | SURVEILLANCE RESPONSIBILITY | | DATA LINK RESPONSIBILITY |
|------------------------|-----------------------------|-----------|--------------------------|
| | PRIMARY | SECONDARY | |
| Burbank | -- | -- | -- |
| Long Beach | C | B, D | C |
| Los Angeles (LAX-4) | A, B | -- | A, B |
| Ontario | D | C, A | D |

TABLE 6

DABS SENSOR SURVEILLANCE AND DATA-LINK ZONE ASSIGNMENTS
FOR LOS ALAMITOS ANALYSIS WITH TWO DABS SENSORS
(Scenario 4; See Figure 1)

| SITE | SURVEILLANCE RESPONSIBILITY | | DATA-LINK RESPONSIBILITY |
|------------------------|-----------------------------|-----------|--------------------------|
| | PRIMARY | SECONDARY | |
| Los Angeles (LAX-4) | A, B | C, D | A, B |
| Ontario | C, D | A, B | C, D |

Long Beach Simulations

Four scenarios were evaluated to determine the impact of DABS on ATCRBS at Long Beach. Scenario 1 was used to examine the performance at Long Beach using the existing ATCRBS ground environment. Scenarios 2, 3, and 4 utilized the mixed DABS/ATCRBS ground environment.

Scenario 2 was used to examine the impact on ATCRBS with the DABS sensors restricting their transmissions to surveillance only. (See APPENDIX A for detailed descriptions of the various data-link services.)

For Scenario 3, each aircraft received data-link service and surveillance service from its primary sensor and, in addition, each A/C received one surveillance interrogation per scan from its secondary sensor.

For Scenario 4, all of the air carrier and high-performance general aviation aircraft (83 A/C) were equipped to receive high-option CDTI service and surveillance service from their primary sensor. Three hundred and thirty of the general aviation aircraft were equipped to receive mid option CDTI and surveillance. The remaining 330 aircraft were equipped to receive all of the remaining data-link services (ATC, ATARS/PWI, weather, ATIS, and navigation). This is a worst case involving far more capable avionics than really could be expected to exist in every aircraft.

Furthermore, to increase the severity of the test of DABS interference for Scenarios 2, 3, and 4, it was assumed that El Toro had failed, whereupon its surveillance responsibilities were assumed by Burbank and Ontario. El Toro's data-link responsibilities were assumed by Los Angeles (LAX-4). These modified zone responsibilities are summarized in TABLE 7.

Effective Suppression Rate

There are three mechanisms other than bonafide interrogations that result in the desensitization of a DABS (or ATCRBS) transponder: misaddressed interrogations, DABS sidelobe suppressions, and ATCRBS sidelobe suppressions. Misaddressed interrogations result in a DABS transponder being inhibited during the period of the interrogation from decoding subsequent transmissions.

Therefore, an effective suppression rate is determined by combining the misaddressed interrogation rate with the ATCRBS and DABS sidelobe suppression rates. Since the misaddressed interrogation rate and the DABS sidelobe suppression rate are dependent upon the DABS sensor's instantaneous azimuth, this effective suppression rate will vary with time.

It should be mentioned that DABS roll-call interrogations are structured to suppress ATCRBS transponders for $35 \pm 10 \mu s$.

TABLE 7

MODIFIED DABS SENSOR SURVEILLANCE AND DATA-LINK ZONE
ASSIGNMENTS FOR LONG BEACH ANALYSIS WITH EL TORO INOPERATIVE
(Scenarios 2, 3, 4; see Figure 2)

| SITE | SURVEILLANCE RESPONSIBILITY | | DATA-LINK RESPONSIBILITY |
|------------------------|-----------------------------|-----------|--------------------------|
| | PRIMARY | SECONDARY | |
| Burbank | A | B, D | A |
| Los Angeles (LAX-4) | B, C | -- | B, C |
| El Toro | -- | -- | -- |
| Ontario | D | A, C | D |

SECTION 3

RESULTS

LOS ALAMITOS

The Los Alamitos results are based on a 3-scan (3 seconds of real time per scan) simulation of each scenario.^a The uplink data (interrogation rate, suppression rate and probability of reply) and downlink data (fruit rates and interrogator performance) are summarized in TABLES 8 and 9 and discussed below.

Transponder Performance

Effective Suppression Rate. Replacement of the four ATCRBS interrogators with DABS sensors resulted in decreased effective suppression rates for all of the scenarios. The average sidelobe suppression rate in the all-ATCRBS ground environment was 1048/s. With four DABS sensors deployed, the computed suppression rate was 722/s when the DABS transactions were restricted to surveillance coverage. This increased to 847/s with the increased data-link services of scenario 3. With two DABS sensors (scenario 4) the effective suppression rate was 969/s.

ATCRBS Interrogation Rates. The average ATCRBS interrogation rate decreased from 395/s to 385/s as a result of replacing four ATCRBS interrogators with DABS sensors. With only two ATCRBS sites converted, the interrogation rate was computed to be 390/s.

Probability of Reply. The probability of reply is inversely proportional to the suppression rate. This is due to the deadtime associated with suppressions. The baseline (all-ATCRBS ground environment) probability of reply was computed to be 93.9%. With DABS introduced and its channel activity restricted to "surveillance only" roll-call interrogations, the probability of reply increased

^aThe validity of predictions based on 3-scan simulations is addressed in the subsection Spatial and Temporal Peaking.

TABLE 8

TRANSPONDER PERFORMANCE AT LOS ALAMITOS 3-SCAN AVERAGE

| SCENARIO ^a | AVERAGE NUMBER OF ATCRBS INTERROGATIONS ARRIVING AT EACH A/C PER SECOND | AVERAGE NUMBER OF DABS ALL-CALL INTERROGATIONS ARRIVING AT EACH A/C PER SECOND | AVERAGE NUMBER OF DABS ROLL-CALL INTERROGATIONS ARRIVING AT EACH A/C PER SECOND | AVERAGE NUMBER OF EFFECTIVE SUP- PRESSIONS ARRIVING AT EACH A/C PER SECOND ^b | AVERAGE PROBABILITY OF REPLY |
|-----------------------|--|---|--|---|---------------------------------------|
| 1 | 395 | -- | -- | 1048 | 93.9 |
| 2 | 385 | 0.31 | 0.25 | 722 | 94.8 |
| 3 | 385 | 0.31 | 0.77 | 847 | 94.8 |
| 4 | 390 | 0.15 | 0.56 | 969 | 94.5 |

- a Scenario 1 (ATCRBS Baseline)
 Scenario 2 (DABS Surveillance)
 Scenario 3 (DABS Surveillance, plus Data Link)
 Scenario 4 (DABS Surveillance, plus Data Link with CDTI)
- b Includes ATCRBS SL suppressions, DABS SL suppressions, misaddressed DABS interrogations and DABS all-calls when "locked-out".

TABLE 9
INTERROGATOR PERFORMANCE AT LOS ALAMITOS 3-SCAN AVERAGE

| SCENARIO ^a | ATCRBS FRUIT PER SECOND | DABS ALL-CALL FRUIT PER SECOND | DABS ROLL-CALL FRUIT PER SECOND | % OF DESIRED REPLIES OVERLAPPED BY DABS ALL-CALL FRUIT | % OF DESIRED REPLIES OVERLAPPED BY DABS ROLL-CALL FRUIT | % OF DESIRED REPLIES OVER- LAPPED BY ATCRBS FRUIT |
|-----------------------|----------------------------|-----------------------------------|------------------------------------|--|---|--|
| 1 | 4558 | -- | -- | -- | -- | 0.04 |
| 2 | 4510 | 7.5 | 2.2 | 0.01 | 0.02 | 0.04 |
| 3 | 4505 | 7.5 | 1.5 | 0.06 | 0.02 | 0.04 |
| 4 | 4522 | 3.7 | 3.0 | 0.01 | 0.03 | 0.04 |

^a Scenario 1 (ATCRBS Baseline)
 Scenario 2 (DABS Surveillance)
 Scenario 3 (DABS Surveillance, plus Data Link)
 Scenario 4 (DABS Surveillance, plus Data Link with CDTI)

to 94.8%. With increased channel occupancy (data-link and extended-length data-link services), the average transponder probability of reply decreased to 94.5%.

Interrogator Performance

ATCRBS Fruit. The reduced ATCRBS interrogation rates due to DABS deployment resulted in a reduction of ATCRBS fruit by about 3 percent (see TABLE 9).

DABS Fruit. With four DABS sensors deployed, the DABS all-call fruit rate was computed to be about 7.5 per second (scenarios 2 and 3). With only two DABS sensors deployed, the all-call fruit rate decreased to about 3.7 per second (scenario 4).

With four DABS sensors deployed and their transmissions restricted to surveillance interrogations, the DABS roll-call fruit rate was 2.2 per second (scenario 2). When the DABS services were expanded to include surveillance and data-link transactions, the roll-call fruit rate decreased to about 1.5 per second (scenario 3).

The DABS roll-call fruit rate with just two sensors deployed (scenario 4) was computed to be 3 per second.

Video Display. The combined effect of both DABS all-call and DABS roll-call fruit resulted in less than 0.1 per cent of the desired replies being overlapped and obscured by the multiple response initiated by a DABS fruit. These results are summarized in TABLE 9.

LONG BEACH

It was felt that a simulation run of 1-scan duration (here 4.6 seconds) is sufficient to achieve a useful level of accuracy. To verify this, three statistically independent simulation runs were carried out, so that the results can be compared. Each of the three samples was initiated with random start angles of antenna rotation and random phases of the interrogation clocks. TABLES 12 and 13 give detailed results of the three single-scan samples (sets). Overall average values were also computed and these are given in TABLES 10 and 11.

TABLE 10
TRANSPONDER PERFORMANCE AT LONG BEACH; 3-SCAN AVERAGE

| SCENARIO ^a | AVERAGE NUMBER OF ATCRBS INTERROGATIONS ARRIVING AT EACH A/C PER SECOND | AVERAGE NUMBER OF DABS ALL-CALL INTERRO- GATIONS ARRIVING AT EACH A/C PER SECOND | AVERAGE NUMBER OF DABS ROLL-CALL INTERRO- GATIONS ARRIVING AT EACH A/C PER SECOND | AVERAGE NUMBER OF EFFECTIVE SUP- PRESSIONS ARRIVING AT EACH A/C PER SECOND | AVERAGE PROBABILITY OF REPLY |
|-----------------------|--|---|--|--|---------------------------------------|
| 1 | 324 | -- | -- | 759 | 95.8 |
| 2 | 312 | 0.71 | 0.43 | 596 | 96.4 |
| 3 | 312 | 0.71 | 0.67 | 610 | 96.4 |
| 4 | 312 | 0.73 | 1.28 | 705 | 95.9 |

a Scenario 1 (ATCRBS Baseline)
 Scenario 2 (DABS Surveillance)
 Scenario 3 (DABS Surveillance, plus Data Link)
 Scenario 4 (DABS Surveillance, plus Data Link with CDTI)

TABLE 11
INTERROGATOR PERFORMANCE AT LONG BEACH

| SCENARIO ^a | P (DETECTION) | P (VAL-A) ^b | P (VAL-C) ^b | ATCRBS FRUIT PER SECOND | DABS ALL-CALL FRUIT PER SECOND | DABS ROLL-CALL FRUIT PER SECOND |
|-----------------------|---------------|------------------------|------------------------|----------------------------|-----------------------------------|------------------------------------|
| 1 | 96.4 | 80.8 | 72.7 | 10830 | - | - |
| 2 | 96.4 | 80.7 | 72.3 | 10480 | 11.1 | 10.5 |
| 3 | 96.4 | 80.7 | 72.3 | 10491 | 11.1 | 18.0 |
| 4 | 96.6 | 80.6 | 71.8 | 10427 | 10.8 | 37.4 |

a Scenario 1 (ATCRBS Baseline)
 Scenario 2 (DABS Surveillance)
 Scenario 3 (DABS Surveillance, plus Data Link)
 Scenario 4 (DABS Surveillance, plus Data Link with CDTI)

b Probability of mode validation given that the A/C was detected.

TABLE 12
 UPLINK RATES AT LONG BEACH; PER SCAN AVERAGE

| SCENARIO ^a | AVERAGE NUMBER OF ATCRBS INTERROGATIONS ARRIVING AT EACH A/C PER SECOND | | | AVERAGE NUMBER OF DABS ALL-CALL INTERROGATIONS ARRIVING AT EACH A/C PER SECOND | | | AVERAGE NUMBER OF DABS ROLL-CALL INTERROGATIONS ARRIVING AT EACH A/C PER SECOND | | | AVERAGE NUMBER OF EFFECTIVE SUPPRESSIONS ARRIVING AT EACH A/C PER SECOND | | | AVERAGE PROBABILITY OF REPLY % | | |
|-----------------------|--|-----|-----|--|------|------|---|------|------|---|-----|-----|--------------------------------------|------|------|
| | SET | | | SET | | | SET | | | SET | | | SET | | |
| | 1 | 2 | 3 | 1 | 2 | 3 | 1 | 2 | 3 | 1 | 2 | 3 | 1 | 2 | 3 |
| 1 | 315 | 307 | 349 | - | - | - | - | - | - | 756 | 748 | 772 | 96.1 | 95.7 | 95.7 |
| 2 | 286 | 303 | 346 | 1.75 | 0.25 | 0.12 | 0.86 | 0.37 | 0.06 | 618 | 586 | 583 | 96.4 | 96.5 | 96.1 |
| 3 | 286 | 303 | 346 | 1.75 | 0.25 | 0.12 | 1.24 | 0.51 | 0.27 | 633 | 597 | 599 | 96.6 | 96.4 | 96.1 |
| 4 | 286 | 303 | 346 | 1.86 | 0.20 | 0.12 | 2.75 | 0.82 | 0.27 | 756 | 692 | 668 | 95.9 | 96.1 | 95.8 |

- a Scenario 1 (ATCRBS Baseline)
 Scenario 2 (DABS Surveillance)
 Scenario 3 (DABS Surveillance, plus Data Link)
 Scenario 4 (DABS Surveillance, plus Data Link with CDTI)

TABLE 13

DOWNLINK RATES AT LONG BEACH; PER SCAN AVERAGE

| SCENARIO ^a | P (DETECTION). | | | P (VAL-A) ^b | | | P (VAL-C) ^b | | | ATCRBS FRUIT PER SECOND | | | DABS ALL-CALL FRUIT PER SECOND | | | DABS ROLL- CALL FRUIT PER SECOND | | |
|-----------------------|----------------|------|------|------------------------|------|------|------------------------|------|------|-------------------------|------|-------|--------------------------------|-----|-----|----------------------------------|------|------|
| | SET | | | SET | | | SET | | | SET | | | SET | | | SET | | |
| | 1 | 2 | 3 | 1 | 2 | 3 | 1 | 2 | 3 | 1 | 2 | 3 | 1 | 2 | 3 | 1 | 2 | 3 |
| 1 | 96.3 | 96.8 | 96.7 | 80.0 | 81.7 | 80.8 | 71.5 | 72.6 | 72.1 | 11649 | 9088 | 11752 | - | - | - | - | - | - |
| 2 | 96.3 | 96.3 | 96.7 | 79.9 | 81.6 | 80.6 | 71.6 | 72.9 | 72.4 | 11073 | 8851 | 11516 | 19.9 | 3.5 | 9.9 | 15.8 | 3.5 | 12.1 |
| 3 | 96.3 | 96.3 | 96.7 | 79.7 | 81.8 | 80.6 | 71.6 | 73.1 | 72.1 | 11092 | 8866 | 11514 | 19.9 | 3.5 | 9.9 | 23.4 | 10.6 | 19.9 |
| 4 | 96.3 | 96.4 | 97.0 | 79.6 | 81.8 | 80.5 | 71.1 | 72.7 | 71.7 | 10999 | 8796 | 11486 | 18.4 | 4.2 | 9.9 | 45.5 | 30.5 | 36.2 |

^a Scenario 1 (ATCRBS Baseline)

Scenario 2 (DABS Surveillance)

Scenario 3 (DABS Surveillance, plus Data Link)

Scenario 4 (DABS Surveillance, plus Data Link with CDTI)

^b Probability of VALIDATION given that the A/C was detected.

Transponder Performance

Effective Suppression Rate. Deployment of DABS resulted in a decrease in the average effective suppression rate. With the existing all-ATCRBS ground environment, the average sidelobe suppression rate was 759/s.^a With four DABS sites deployed and their transmissions limited to "surveillance only" the suppression rate was reduced to 596/s. The suppression rate increased with the increased DABS channel activity associated with scenarios 3 and 4, but even in the very highest DABS case (scenario 4) remained below the original ATCRBS-only-level.

ATCRBS Interrogation Rate. The average ATCRBS interrogation rate decreased from 324/s to 312/s as a result of replacing four ATCRBS interrogations with DABS sensors.

Probability of Reply. The probability of reply with the all ATCRBS ground environment was computed to be 95.8%. When DABS operations consisted of "surveillance only" the probability of reply increased to 96.4%. With increased channel occupancy (data-link plus CDTI) the probability of reply decreased to 95.9%.

^a Although the Long Beach and the Los Alamitos analyses used the same aircraft deployment, each examined a different sample of A/C. In particular, Los Alamitos monitored only those A/C within a 40 nmi radius while Long Beach's coverage extended to 60 nmi. Since the concentration of interrogators decreased with increased range (from both sites), the average sidelobe suppression rate decreases when averaging over A/C remote from the sidelobes of any interrogator.

Interrogator Performance

ATCRBS Fruit. The reduced ATCRBS interrogation rate due to the replacement of four ATCRBS interrogators with DABS sensors resulted in the ATCRBS fruit rate being reduced by about 3 percent (see TABLE 11).

DABS Fruit. With DABS deployed, the DABS all-call fruit rate was computed to be 11 per second (scenarios 2, 3, and 4).

The DABS roll-call fruit rate with DABS transmissions restricted to surveillance interrogations (scenario 2) was computed to be 10.5 per second. With surveillance plus data-link services (scenario 3) the roll-call fruit rate increased to 18.0 per second. CDTI services further increased the rate to 37.4 per second (scenario 4).

Detection and Mode Validation. There was less than a 1-percent change in both the detection probability and the mode validation probabilities with DABS deployed.

SPATIAL AND TEMPORAL PEAKING

In this section, a more detailed study is made of spatial peaking and temporal peaking. The ATCRBS sidelobe suppression rate at any one aircraft is essentially a constant, which is determined by: 1) the number of interrogators whose sidelobes contain A/C, and 2) the respective interrogator repetition frequencies. The nature of a DABS transponder's response to a misaddressed DABS roll-call interrogation justifies combining the misaddressed interrogation rate with the ATCRBS and DABS sidelobe suppression rates to determine the deadtime at an aircraft. The suppression rate divided by 286^a gives the percentage of deadtime. Since a DABS antenna rotates, and interrogates only a subset of those aircraft within its range, the effective suppression rate due to DABS transmissions will vary with time.

^aThe arrival of 286 suppressions at a transponder in 1 second results in 10,000 us of deadtime which is 1% of a second.

TABLE 14
VARIATION OF THE EFFECTIVE SUPPRESSION RATE; 6-SCAN SIMULATIONS

| SCAN | AVERAGE NUMBER OF EFFECTIVE SUPPRESSIONS ARRIVING AT EACH A/C PER SECOND ^a | |
|---------|--|-----|
| | I | II |
| 1 | 849 | 953 |
| 2 | 811 | 815 |
| 3 | 757 | 771 |
| 4 | 1001 | 866 |
| 5 | 816 | 758 |
| 6 | 759 | 893 |
| AVERAGE | 832 | 843 |

^aThe effective suppression rate was determined by combining the mis-addressed interrogation rate with the ATCRBS and DABS sidelobe suppression rates.

Section 3

Los Alamitos

Two 6-scan simulations were conducted to investigate the validity of ATCRBS performance predictions that are based on 3-scan simulations. These simulations used the DABS channel activity described for the Los Alamitos scenario 3. Each simulation was initiated with random start angles and phases. Only the effective suppression rate was computed since it is the predominant contributing factor to ATCRBS degradation. TABLE 14 lists the results of these simulations. It should be noted that although the effective suppression rate varies from 771/s to 1001/s on a per-scan basis, the overall 6-scan averages were 832/s and 843/s. These rates are nearly identical to the 3-scan average rate of 848/s (see TABLE 8). Thus, it can be concluded that 3-scan simulations are sufficiently long to eliminate transient anomalies and accurately predict ATCRBS performance.

Long Beach Map of Transponder Deadtime

Figure 5 illustrates the LA-82 aircraft deployment and the corresponding percentage of transponder deadtime with DABS providing surveillance, data-link and CDTI services. The environment about Long Beach was partitioned into 5 nmi squares; each data-point on the A/C deployment plot gives the number of A/C within a 5 nmi square, and the corresponding point on the % deadtime plot gives the average percentage of deadtime sustained by those A/C. This plot was obtained using the data from the Long Beach scenario 4, set 3. (Also shown are the I_0 and the four DABS sensors.) It can be seen that those aircraft just south of Long Beach were the most heavily affected. To examine the time dependence of the effective deadtime, a 6-scan simulation was conducted where only suppression rates were computed. Figure 6 illustrates the deadtime when averaged after 6 complete scans. It can be seen that the peak of 10% deadtime south of Long Beach decreased to 6%. With an all-ATCRBS ground environment the average deadtime for these aircraft was 4% (see Figure 7).

TABLES B-1 and B-2 (see APPENDIX B) summarize the performance of the 30 aircraft south of Long Beach ($120^\circ < \theta < 240^\circ$) within a range of 9 nmi with the existing ATCRBS ground environment and with DABS deployed, respectively.

[illegible]

Figure 5. Transponder deadtime for Long Beach (Scenario 4-Set 2, 1 scan).
(For meaning of letters and numbers, see p. 33.)

EACH HORIZONTAL INCREMENT REPRESENTS A DISTANCE OF 4.90 MILES.
EACH VERTICAL INCREMENT REPRESENTS A DISTANCE OF 4.97 MILES.

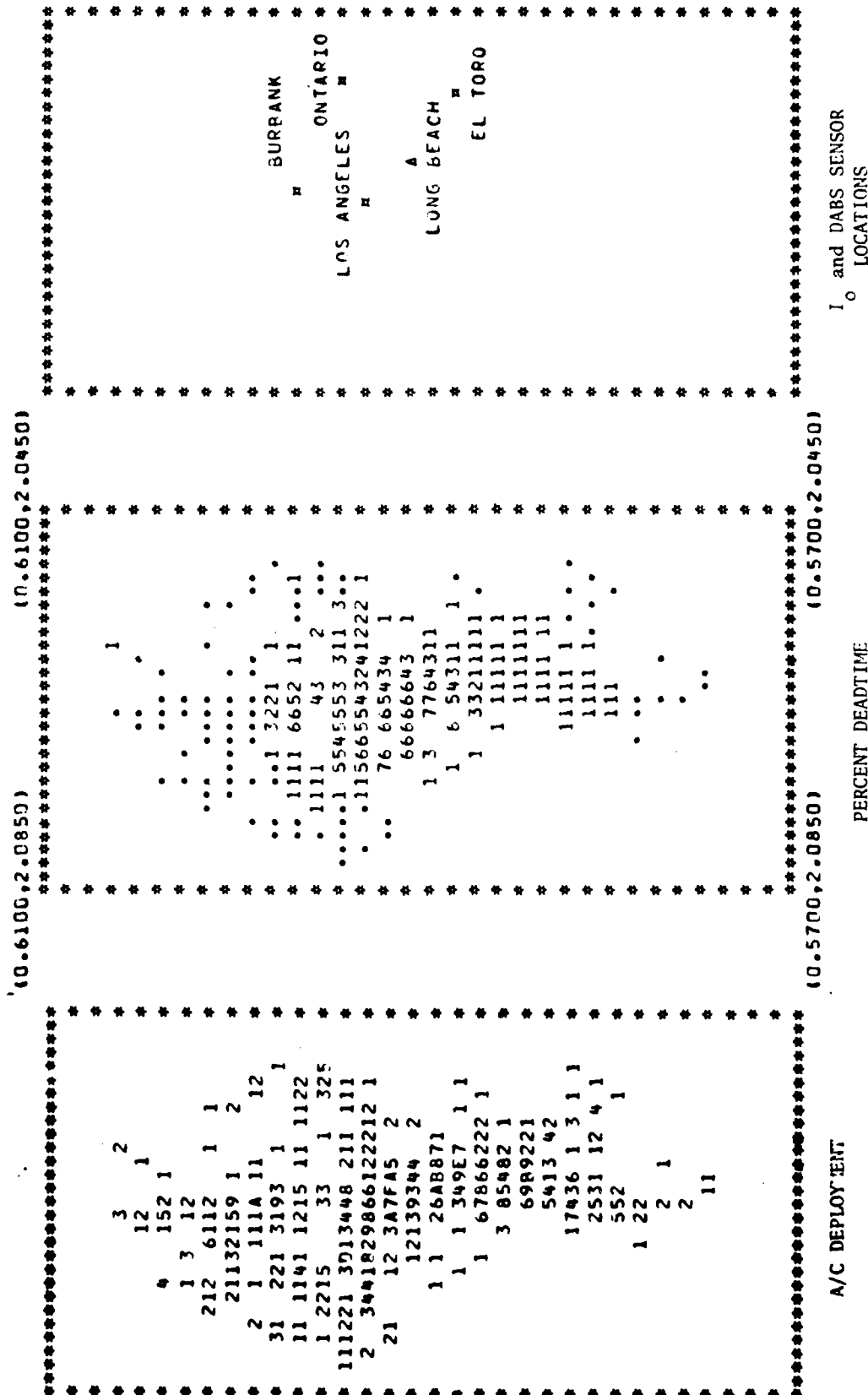


Figure 6. Transponder deadtime for Long Beach (Scenario 4-Set 2, 6 scan average).

(For meaning of numbers and letters, see p. 33.)

Section 3

This data is taken from the Long Beach Scenarios 1 and 4 (sets 1-3). It can be seen that the performance of the transponders was not affected by DABS operations.

Also of interest is the performance of those transponders within the sidelobes of a DABS sensor, since they will be suppressed each time that the sensor transmits an interrogation. However, it was observed that the performance of those A/C within 5 nmi of the Burbank sensor and those within 5 nmi of Los Angeles sensor were not affected by DABS operations. These results are summarized in APPENDIX B.

Figure 8 illustrates the average transponder deadtime after 6 complete scans with an all-ATCRBS ground environment. A comparison of Figure 7 (1 scan with an all-ATCRBS ground environment) with Figure 8 demonstrates the time independence of the ATCRBS sidelobe-suppression rate.

SYMBOLY FOR FIGURES 5 THROUGH 8

| SYMBOL | NUMBER | SYMBOL | NUMBER |
|--------|--------|--------|--------|
| • | 0 | A | 10 |
| 1 | 1 | B | 11 |
| 2 | 2 | C | 12 |
| 3 | 3 | D | 13 |
| 4 | 4 | E | 14 |
| 5 | 5 | F | 15 |
| 6 | 6 | G | 16 |
| 7 | 7 | H | 17 |
| 8 | 8 | I | 18 |
| 9 | 9 | J | 19 |

EACH HORIZONTAL INCREMENT REPRESENTS A DISTANCE OF 4.90 MILES.
EACH VERTICAL INCREMENT REPRESENTS A DISTANCE OF 4.97 MILES.

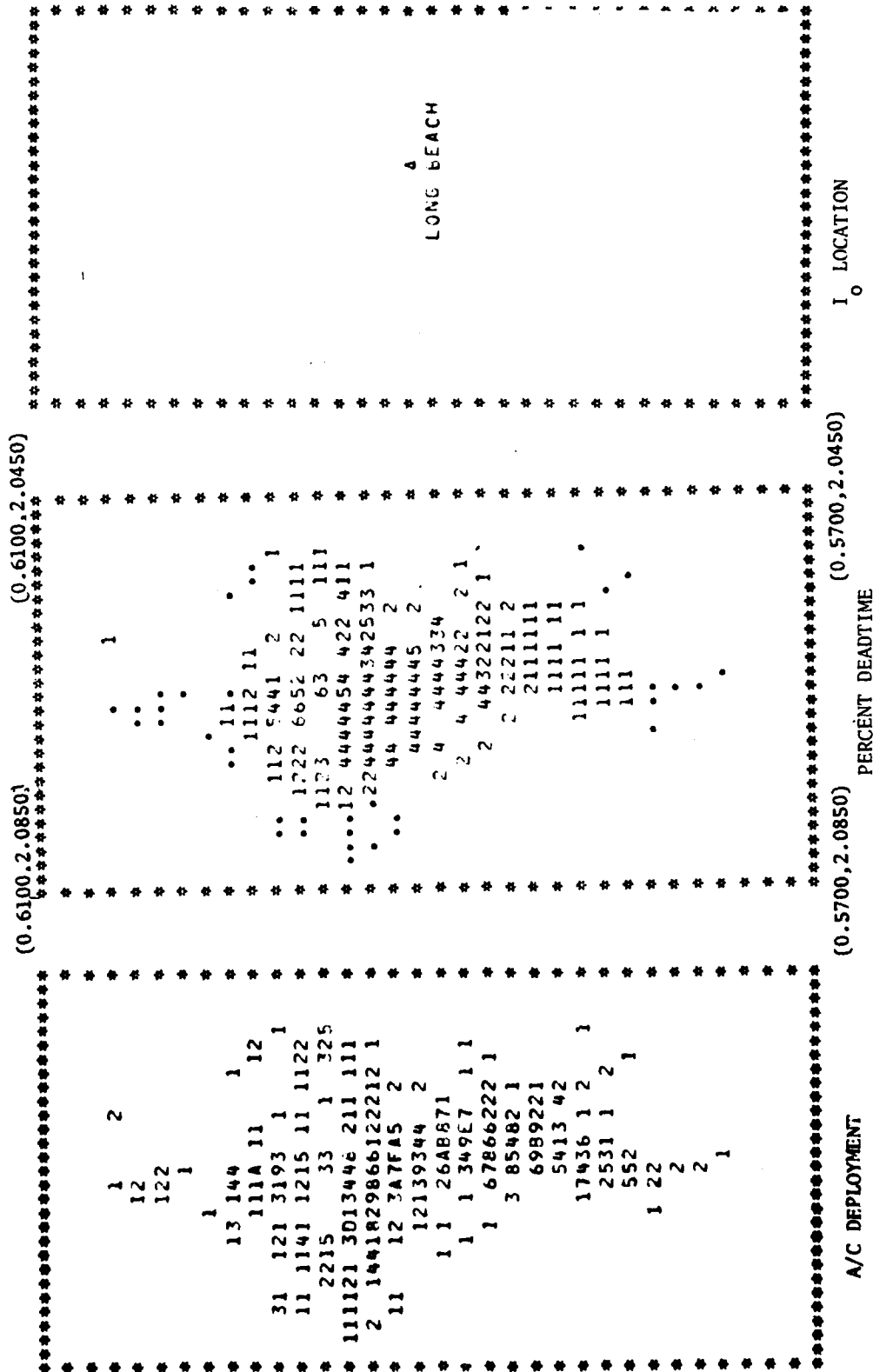


Figure 7. Transponder deadtime for Long Beach (Scenario 1-Set 2, 1 scan).

(For meaning of numbers and letters, see p. 33.)

EACH HORIZONTAL INCREMENT REPRESENTS A DISTANCE OF 4.97 MILES.
EACH VERTICAL INCREMENT REPRESENTS A DISTANCE OF 4.97 MILES.

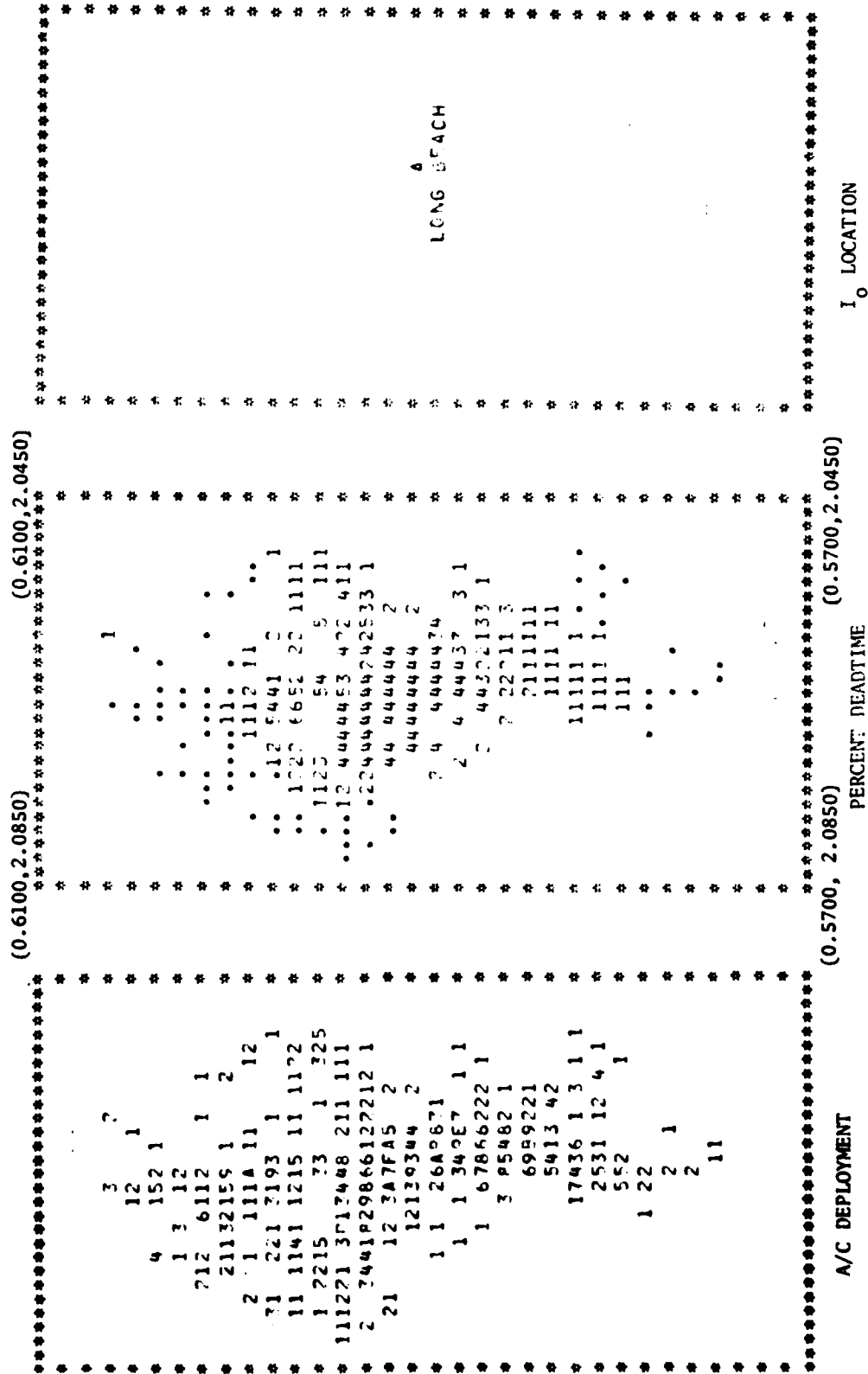


Figure 8. Transponder deadtime for Long Beach (Scenario 1-Set 2, 6 scan average).
(For meaning of numbers and letters, see p. 33.)

SECTION 4
CONCLUSIONS

1. The performance of ATCRBS at both the Los Alamitos and the Long Beach site was relatively unaffected by DABS operations. This was evidenced by the simulation results: that at Los Alamitos less than 1 percent of the desired replies were overlapped by DABS fruit; at Long Beach, there was less than a 1 percent change in both the detection and mode validation probabilities with DABS deployed.

2. With the maximum DABS channel activity (surveillance, data-link, and CDTI services), the average suppression rate did not exceed that in the all-ATCRBS ground environment.

3. There were regions where the DABS suppression rate exceeded the ATCRBS sidelobe suppression rate; however, there was no degradation in the ability of the interrogator of interest to detect and validate targets in these regions.

APPENDIX A
DABS SERVICES

SURVEILLANCE ONLY (LONG BEACH AND LOS ALAMITOS)

Each A/C receives one surveillance interrogation per scan from both its primary and secondary sensor. Each received surveillance interrogation elicited a surveillance reply.

DATA LINK SERVICES

Los Alamitos (Scenarios 3 and 4)

Extended length data-link service consisted of nine comm-C and one comm-A interrogations per scan.^a The first seven comm-C segments were contained within a precursor and did not elicit replies. The remaining two comm-C segments each elicited a comm-D reply. The comm-A interrogation elicited 0.5 comm-B and 0.5 surveillance replies.^b Standard data-link service consisted of 2.5 comm-A interrogations per scan; these elicited 0.5 comm-B and 2.0 surveillance replies.^c

Long Beach

1. Scenario 3 - Data-link service consisted of $(1+P)$ comm-A interrogations per scan where P is a random variable of Poisson Distribution with a mean of 1.0 for air carrier and 0.7 for all other aircraft. Each comm-A interrogation elicited a surveillance reply.

^aSee Reference 3 for definitions of the various types of interrogations.

^b50 percent of the time a comm-A interrogation elicited a comm-B reply, and the other 50 percent of the time the comm-A interrogation elicited a surveillance reply. This was accomplished using Monte Carlo techniques.

^c50 percent of the time two comm-A interrogations were transmitted, eliciting two surveillance replies and the other 50 percent of the time three comm-A interrogations were transmitted eliciting two surveillance replies and one comm-B reply. This was accomplished using Monte Carlo techniques.

Appendix A

2. Scenario 4 - High Option CDTI messages consisted of a series of comm-C segments addressed to a particular aircraft, which contain information about other aircraft (targets) in the immediate vicinity (within the threat volume) of the addressed aircraft. The threat volume was arbitrarily chosen to extend for 3 nmi radially and within an altitude of ± 2500 ft. This entailed transmitting $(T/2+2.5)$ ru comm-C segments per scan, where T was the number of targets within the threat volume (ru denotes "rounding upward" to the next larger integer). All but two of the comm-C segments were contained within a precursor, and did not elicit replies. The remaining two comm-C segments each elicited a comm-D reply.

Mid-Option CDTI consisted of $(T/2)$ ru + P comm-A interrogations per scan, where P is a random variable of Poisson distribution with a mean of 0.7. Each comm-A transaction either contained data for two targets or contained data for one target plus an ATARS command. All but one of the comm-A interrogations elicited surveillance replies. The remaining comm-A interrogation elicited a comm-B reply. If both T and P for a particular aircraft were computed to be zero, the A/C received one surveillance interrogation per scan from its primary sensor. Data-link coverage was identical to that described for scenario 3 above, however, the mean of P was fixed at 0.7.

APPENDIX B

IMPACT OF DABS SUPPRESSION RATES

The ATCRBS sidelobe suppression rate at any one aircraft is essentially a constant, which is determined by: 1) the number of interrogators whose sidelobes contain the A/C, and 2) the respective interrogator repetition frequencies. The nature of a DABS transponder's response to a misaddressed interrogation justifies combining the misaddressed interrogation rate with the ATCRBS and DABS sidelobe suppression rates to determine the deadtime at an aircraft. The suppression rate divided by 286 gives the percentage of deadtime.^a Since a DABS sensor rotates, and interrogates only a subset of those aircraft within its range, the effective suppression rate due to DABS transmissions will vary with time.

TABLES B-1 and B-2 summarize the performance of the 30 transponders south of Long Beach ($120^\circ < \theta < 240^\circ$) within a range of 9 nmi with the existing ATCRBS ground environment and with DABS deployed respectively. This data is taken from the Long Beach scenarios 1 and 4 (SETS 1-3). It can be seen that the performance of the transponders was not affected by DABS operations.

Also of interest are the performance of those transponders within the sidelobes of a DABS sensor since they will be suppressed each time that the sensor transmits an interrogation. TABLE B-3 gives the performance of the aircraft within 5 nmi of the Burbank sensor with the all-ATCRBS ground environment while TABLE B-4 summarizes their performance with DABS deployed. Again, it can be seen that the transponder performance was not degraded by DABS.

Similarly, the performance of the 37 transponders within 5 nmi of the Los Angeles sensor were not affected by DABS operations. This result is summarized in TABLES B-5 and B-6.

^aThe arrival of 286 suppressions at a transponder in one second results in 10,000 μ s of deadtime which is 1% of a second.

TABLE B-1

PERFORMANCE OF A/C SOUTH OF LONG BEACH ($0 < r < 9$ nmi; $120 < \theta < 240^\circ$) WITH
EXISTING ALL ATRBS GROUND ENVIRONMENT

| A/C | SET 1 | | | | SET 2 | | | | SET 3 | | | |
|-----|-------------------------|---------------------|----------------------|-----------|-------------------------|---------------------|----------------------|-----------|-------------------------|---------------------|----------------------|-----------|
| | SUPPS. PER SECOND | MISSED DETECTION | MISSED VALIDATION | | SUPPS. PER SECOND | MISSED DETECTION | MISSED VALIDATION | | SUPPS. PER SECOND | MISSED DETECTION | MISSED VALIDATION | |
| | | | Mode A | Mode C | | | Mode A | Mode C | | | Mode A | Mode C |
| 1 | 956 | | | | 1208 | | | | 1112 | | | |
| 2 | 1229 | | | | 1229 | | | | 1209 | | | |
| 3 | 1209 | | | | 1190 | | | | 1248 | | | |
| 4 | 1209 | | | | 1268 | | | | 1209 | | | |
| 5 | 1268 | | | | 1268 | | | | 1268 | | | |
| 6 | 1268 | | | | 1326 | | | | 1248 | | | |
| 7 | 1229 | | | | 1268 | | | | 1229 | | | |
| 8 | 1268 | | | | 956 | | | | 1229 | | | |
| 9 | 1224 | | | | 1229 | | | | 1326 | | | |
| 10 | 1224 | | | | 1287 | | | | 1268 | | | |
| 11 | 1209 | | | | 1229 | | | | 1248 | | | |
| 12 | 1209 | | | | 1209 | | | | 1287 | | | |
| 13 | 1229 | | | ✓ | 1229 | | | | 1209 | | | |
| 14 | 1287 | | | | 1287 | | | | 1268 | | | |
| 15 | 897 | | | | 1248 | | | | 878 | | | |
| 16 | 1112 | | | | 1307 | | | | 897 | | | |
| 17 | 1229 | | | | 1229 | | | | 1209 | | | |
| 18 | 1307 | | | | 1209 | | | | 1190 | | | |
| 19 | 1268 | | | | 1209 | | | | 1190 | | | |

TABLE B-1 (Continued)

| A/C | SET 1 | | | | SET 2 | | | | SET 3 | | | |
|-------|-------------------------|---------------------|----------------------|-----------|-------------------------|---------------------|----------------------|-----------|-------------------------|---------------------|----------------------|-----------|
| | SUPPS. PER SECOND | MISSED DETECTION | MISSED VALIDATION | | SUPPS. PER SECOND | MISSED DETECTION | MISSED VALIDATION | | SUPPS. PER SECOND | MISSED DETECTION | MISSED VALIDATION | |
| | | | Mode A | Mode C | | | Mode A | Mode C | | | Mode A | Mode C |
| 20 | 1209 | | | | 1229 | | | | 1268 | | | |
| 21 | 1209 | | | | 1287 | | | | 1248 | | | |
| 22 | 1229 | | | | 1209 | | | | 1209 | | | |
| 23 | 1209 | | | | 995 | | | | 1209 | | | |
| 24 | 1287 | | | | 1248 | | | | 1268 | | | |
| 25 | 1014 | | | | 1229 | | | | 956 | | | |
| 26 | 1229 | | | | 1209 | | | | 1229 | | | |
| 27 | 1248 | | | | 1190 | | | ✓ | 1229 | | ✓ | |
| 28 | 1348 | | | | 1131 | | | | 1229 | | | |
| 29 | 1229 | | | | 1229 | | | | 1209 | | | |
| 30 | 1229 | | ✓ | ✓ | 1229 | | ✓ | ✓ | 1248 | | ✓ | ✓ |
| TOTAL | | 0 | 1 | 2 | | 0 | 1 | 2 | | 0 | 2 | 1 |

TABLE B-2
 PERFORMANCE OF A/C SOUTH OF LONG BEACH ($0 < r < 9$ nmi, $120 < \theta < 240^\circ$)
 WITH DABS DEPLOYED

| A/C | SET 1 | | | | SET 2 | | | | SET 3 | | | |
|-----|-------------------------|---------------------|----------------------|-----------|-------------------------|---------------------|----------------------|-----------|-------------------------|---------------------|----------------------|-----------|
| | SUPPS. PER SECOND | MISSED DETECTION | MISSED VALIDATION | | SUPPS. PER SECOND | MISSED DETECTION | MISSED VALIDATION | | SUPPS. PER SECOND | MISSED DETECTION | MISSED VALIDATION | |
| | | | Mode A | Mode C | | | Mode A | Mode C | | | Mode A | Mode C |
| 1 | 1814 | | | | 1639 | | | | 1502 | | | |
| 2 | 2243 | | | | 1755 | | | | 1209 | | | |
| 3 | 2496 | | | | 2321 | | | | 995 | | | |
| 4 | 2457 | | | | 2477 | | | | 1053 | | | |
| 5 | 2399 | | | | 2009 | | | | 2112 | | | |
| 6 | 2418 | | | | 1920 | | | | 1092 | | | |
| 7 | 2184 | | | | 2477 | | | | 995 | | | |
| 8 | 2360 | | | | 2555 | | | | 974 | | | |
| 9 | 2067 | | | | 1931 | | | | 1014 | | | |
| 10 | 2067 | | | | 1931 | | | | 1034 | | | |
| 11 | 2948 | | | | 1872 | | | | 995 | | | |
| 12 | 2145 | | | | 2028 | | | | 995 | | | |
| 13 | 2360 | | | | 2399 | | | | 1268 | | | |
| 14 | 2808 | | | | 2360 | | | | 1053 | | ✓ | |
| 15 | 2106 | | | | 2126 | | | | 644 | | | |
| 16 | 1755 | | | | 2282 | | | | 644 | | | |
| 17 | 2126 | | | | 2360 | | | | 1112 | | | |
| 18 | 3237 | | | | 2165 | | | | 975 | | | |
| 19 | 3237 | | | | 2009 | | | | 995 | | | |

TABLE B-2 (Continued)

| A/C | SET 1 | | | | SET 2 | | | | SET 3 | | | |
|-------|-------------------------|---------------------|--------------------------------|--------------------------------|-------------------------|---------------------|--------------------------------|--------------------------------|-------------------------|---------------------|--------------------------------|--------------------------------|
| | SUPPS. PER SECOND | MISSED DETECTION | MISSED VALIDATION Mode A | MISSED VALIDATION Mode C | SUPPS. PER SECOND | MISSED DETECTION | MISSED VALIDATION Mode A | MISSED VALIDATION Mode C | SUPPS. PER SECOND | MISSED DETECTION | MISSED VALIDATION Mode A | MISSED VALIDATION Mode C |
| 20 | 2769 | | | | 2067 | | | | 995 | | | |
| 21 | 995 | | | | 2906 | | | | 1092 | | | |
| 22 | 1092 | | | | 2457 | | | | 1092 | | | |
| 23 | 1112 | | | | 1970 | | | | 1034 | | | |
| 24 | 1209 | | | | 2009 | | | | 1034 | | | |
| 25 | 1034 | | | | 2184 | | | | 702 | | | |
| 26 | 1229 | | | | 2204 | | | | 1053 | | | |
| 27 | 1073 | | | | 3179 | | | ✓ | 1014 | | | |
| 28 | 1112 | | | | 2828 | | | | 974 | | | |
| 29 | 1092 | | | | 2730 | | | | 1014 | | | |
| 30 | 1112 | | ✓ | ✓ | 2418 | | | ✓ | 974 | | ✓ | ✓ |
| TOTAL | | 0 | 1 | 1 | | 0 | 2 | 1 | | 0 | 2 | 1 |

TABLE B-3
PERFORMANCE OF A/C WITHIN 5 nmi OF BURBANK WITH THE
EXISTING ALL ATCRBS GROUND ENVIRONMENT

| A/C | SET 1 | | | | SET 2 | | | | SET 3 | | | |
|-------|-------------------------|---------------------|----------------------|-----------|-------------------------|---------------------|----------------------|-----------|-------------------------|---------------------|----------------------|-----------|
| | SUPPS. PER SECOND | MISSED DETECTION | MISSED VALIDATION | | SUPPS. PER SECOND | MISSED DETECTION | MISSED VALIDATION | | SUPPS. PER SECOND | MISSED DETECTION | MISSED VALIDATION | |
| | | | Mode A | Mode C | | | Mode A | Mode C | | | Mode A | Mode C |
| 1 | 1911 | | | | 1892 | | | | 1872 | | | |
| 2 | 1619 | | | | 1872 | | | | 1697 | | | |
| 3 | 2009 | | | | 1950 | | | | 1892 | | | |
| 4 | 1619 | | | | 1892 | | | | 1697 | | | |
| 5 | 1638 | | | | 1892 | | | | 1677 | | | |
| 6 | 1151 | | | | 1151 | | | | 1268 | | | |
| 7 | 1190 | | | | 1190 | | | | 1131 | | | |
| 8 | 1677 | | | | 1677 | | | | 1853 | | | |
| 9 | 1697 | | | | 1599 | | | | 1592 | | | |
| 10 | 1209 | | | | 1209 | | | | 1404 | | | ✓ |
| 11 | 1151 | | ✓ | ✓ | 1131 | | ✓ | ✓ | 1463 | | ✓ | ✓ |
| 12 | 1151 | | | ✓ | 1190 | | | | 1443 | | | ✓ |
| 13 | 1229 | | | | 1190 | | | | 1326 | | | ✓ |
| TOTAL | | 0 | 1 | 2 | | 0 | 1 | 1 | | 0 | 1 | 4 |

TABLE B-4
PERFORMANCE OF A/C WITHIN 5 nmi OF BURBANK WITH DABS DEPLOYED

| A/C | SET 1 | | | | SET 2 | | | | SET 3 | | | |
|-------|-------------------------|---------------------|----------------------|-----------|-------------------------|---------------------|----------------------|-----------|-------------------------|---------------------|----------------------|-----------|
| | SUPPS. PER SECOND | MISSED DETECTION | MISSED VALIDATION | | SUPPS. PER SECOND | MISSED DETECTION | MISSED VALIDATION | | SUPPS. PER SECOND | MISSED DETECTION | MISSED VALIDATION | |
| | | | Mode A | Mode C | | | Mode A | Mode C | | | Mode A | Mode C |
| 1 | 2282 | | | | 1677 | | | | 2099 | | | |
| 2 | 1872 | | | | 1638 | | | | 2106 | | | |
| 3 | 2828 | | | | 1755 | | | | 1872 | | | |
| 4 | 2457 | | | | 1482 | | | | 1619 | | | |
| 5 | 2516 | | | | 1463 | | | | 1658 | | | |
| 6 | 1716 | | | | 644 | | | | 858 | | | |
| 7 | 1950 | | | | 702 | | | | 800 | | | |
| 8 | 1814 | | | | 1307 | | | ✓ | 2009 | | | |
| 9 | 2555 | | | | 1560 | | | | 2282 | | | |
| 10 | 878 | | | | 800 | | | | 1658 | | | ✓ |
| 11 | 897 | | ✓ | ✓ | 722 | | | ✓ | 1658 | | ✓ | ✓ |
| 12 | 897 | | | ✓ | 780 | | | | 1658 | | ✓ | ✓ |
| 13 | 1897 | | | | 1053 | | | | 1385 | | | ✓ |
| TOTAL | | 0 | 1 | 2 | | 0 | 0 | 2 | | 0 | 2 | 4 |

TABLE B-5
PERFORMANCE OF AIRCRAFT WITHIN 5 nmi OF LOS ANGELES (LAX-4) WITH
EXISTING ALL ATCRBS GROUND ENVIRONMENT

| A/C | SET 1 | | | SET 2 | | | SET 3 | | |
|-----|-------------------------|---------------------|--|-------------------------|---------------------|---|-------------------------|---------------------|--|
| | SUPPS. PER SECOND | MISSED DETECTION | MISSED VALIDATION Mode A Mode C | SUPPS. PER SECOND | MISSED DETECTION | MISSED VALIDATIONS Mode A Mode C | SUPPS. PER SECOND | MISSED DETECTION | MISSED VALIDATION Mode A Mode C |
| 1 | 1287 | | | 1229 | | | 1248 | | |
| 2 | 1248 | | | 1209 | | | 1307 | | |
| 3 | 1248 | | | 1248 | | | 1287 | | |
| 4 | 1248 | | | 1209 | | | 1326 | | |
| 5 | 1229 | | | 1307 | | | 1248 | | |
| 6 | 1190 | | | 1248 | | | 1287 | | |
| 7 | 1287 | | | 1268 | | | 1229 | | |
| 8 | 1268 | | | 1209 | | | 1170 | | |
| 9 | 1229 | | ✓ | 1229 | | ✓ | 1268 | | ✓ |
| 10 | 1268 | | ✓ | 1287 | | | 1209 | | |
| 11 | 1209 | ✓ | ✓ | 819 | | ✓ | 1248 | | ✓ |
| 12 | 1268 | | ✓ | 1248 | | | 1190 | | ✓ |
| 13 | 1229 | | | 1229 | | | 1190 | | |
| 14 | 1209 | | | 1229 | | | 1268 | | |
| 15 | 1229 | ✓ | ✓ | 1229 | ✓ | ✓ | 1229 | ✓ | ✓ |
| 16 | 1229 | | ✓ | 1287 | | ✓ | 1229 | | ✓ |
| 17 | 1248 | | | 1268 | | ✓ | 1229 | | ✓ |
| 18 | 1229 | ✓ | ✓ | 1248 | ✓ | ✓ | 1307 | ✓ | ✓ |
| 19 | 1190 | | ✓ | 1287 | | ✓ | 1248 | | ✓ |

TABLE B-5 (Continued)

| A/C | SET 1 | | | | SET 2 | | | | SET 3 | | | |
|-------|-------------------------|---------------------|------------------------------|----|-------------------------|---------------------|------------------------------|----|-------------------------|---------------------|------------------------------|----|
| | SUPPS. PER SECOND | MISSED DETECTION | MISSED VALIDATION Mode | | SUPPS. PER SECOND | MISSED DETECTION | MISSED VALIDATION Mode | | SUPPS. PER SECOND | MISSED DETECTION | MISSED VALIDATION Mode | |
| | | | A | C | | | A | C | | | A | C |
| 20 | 1190 | | ✓ | ✓ | 1268 | | ✓ | ✓ | 1151 | | ✓ | ✓ |
| 21 | 1248 | | | ✓ | 1326 | | ✓ | ✓ | 995 | | ✓ | ✓ |
| 22 | 1209 | | ✓ | ✓ | 1326 | | ✓ | ✓ | 819 | | ✓ | ✓ |
| 23 | 1190 | | ✓ | ✓ | 1229 | | ✓ | ✓ | 1209 | | ✓ | ✓ |
| 24 | 1190 | | | | 1229 | | | | 1229 | | | ✓ |
| 25 | 1287 | | | ✓ | 1248 | | | | 1209 | | | ✓ |
| 26 | 1209 | | | | 1488 | | | | 1209 | | | |
| 27 | 1229 | | | | 1307 | | | | 1248 | | | |
| 28 | 1209 | | | | 1248 | | | | 1229 | | | |
| 29 | 1340 | | | | 1287 | | | | 1268 | | | |
| 30 | 1229 | | | | 1287 | | | | 1248 | | | |
| 31 | 1190 | | ✓ | ✓ | 1229 | | ✓ | ✓ | 1229 | | ✓ | ✓ |
| 32 | 1229 | | | ✓ | 1287 | | | ✓ | 1229 | | ✓ | ✓ |
| 33 | 1268 | | | | 1268 | | | ✓ | 1209 | | | ✓ |
| 34 | 1209 | ✓ | ✓ | ✓ | 1229 | ✓ | ✓ | ✓ | 1268 | ✓ | ✓ | ✓ |
| 35 | 937 | | | | 1326 | | | | 1209 | | | |
| 36 | 1229 | | | | 1287 | | | | 1229 | | | |
| 37 | 1268 | | ✓ | ✓ | 1287 | | ✓ | ✓ | 1229 | | ✓ | ✓ |
| TOTAL | | 3 | 11 | 17 | | 3 | 14 | 17 | | 3 | 14 | 18 |

TABLE B-6
PERFORMANCE OF TRANSPONDERS WITHIN 5 nmi OF LOS ANGELES (LAX-4)
WITH DABS DEPLOYED

| A/C | SET 1 | | | | SET 2 | | | | SET 3 | | | |
|-----|-------------------------|---------------------|--------------------------------|--------------------------------|-------------------------|---------------------|--------------------------------|--------------------------------|-------------------------|---------------------|--------------------------------|--------------------------------|
| | SUPPS. PER SECOND | MISSED DETECTION | MISSED VALIDATION Mode A | MISSED VALIDATION Mode C | SUPPS. PER SECOND | MISSED DETECTION | MISSED VALIDATION Mode A | MISSED VALIDATION Mode C | SUPPS. PER SECOND | MISSED DETECTION | MISSED VALIDATION Mode A | MISSED VALIDATION Mode C |
| 1 | 995 | | | | 1014 | | | | 2243 | | | |
| 2 | 1151 | | | | 1053 | | | | 2008 | | | |
| 3 | 1112 | | | | 956 | | | | 2008 | | | |
| 4 | 1053 | | | | 1014 | | | | 1424 | | | |
| 5 | 1151 | | | | 975 | | | | 1210 | | | |
| 6 | 1034 | | | | 975 | | | | 1268 | | | |
| 7 | 1073 | | | | 1073 | | | ✓ | 1326 | | | |
| 8 | 1034 | | | | 995 | | | ✓ | 1989 | | | |
| 9 | 1014 | | ✓ | ✓ | 1034 | | | ✓ | 2106 | | ✓ | ✓ |
| 10 | 1053 | | | ✓ | 1073 | | | ✓ | 2009 | | | ✓ |
| 11 | 1014 | | ✓ | ✓ | 1034 | | ✓ | ✓ | 2028 | | ✓ | ✓ |
| 12 | 1053 | | | ✓ | 1092 | | | | 1970 | | | ✓ |
| 13 | 1034 | | | | 1073 | | | | 1892 | | | |
| 14 | 995 | | | | 1053 | | | | 2106 | | | |
| 15 | 1014 | ✓ | ✓ | ✓ | 1092 | ✓ | ✓ | ✓ | 1794 | ✓ | ✓ | ✓ |
| 16 | 976 | | ✓ | ✓ | 1053 | | ✓ | ✓ | 1482 | | ✓ | ✓ |
| 17 | 975 | | | | 936 | | | ✓ | 1424 | | ✓ | ✓ |
| 18 | 1365 | ✓ | ✓ | ✓ | 975 | ✓ | ✓ | ✓ | 1521 | ✓ | ✓ | ✓ |
| 19 | 1326 | | ✓ | ✓ | 959 | | ✓ | ✓ | 1521 | | ✓ | ✓ |

TABLE B-6 (Continued)

| A/C | SET 1 | | | | SET 2 | | | | SET 3 | | | |
|-------|-------------------------|---------------------|----------------------------------|----|-------------------------|---------------------|----------------------------------|----|-------------------------|---------------------|----------------------------------|----|
| | SUPPS. PER SECOND | MISSED DETECTION | MISSED VALIDATION Mode A C | | SUPPS. PER SECOND | MISSED DETECTION | MISSED VALIDATION Mode A C | | SUPPS. PER SECOND | MISSED DETECTION | MISSED VALIDATION Mode A C | |
| 20 | 1346 | | ✓ | | 1014 | | ✓ | | 1385 | | ✓ | ✓ |
| 21 | 1346 | | ✓ | | 1034 | | ✓ | | 1248 | | ✓ | ✓ |
| 22 | 1287 | | ✓ | | 1053 | | ✓ | | 1151 | | ✓ | ✓ |
| 23 | 1346 | | ✓ | | 975 | | ✓ | | 1229 | | ✓ | ✓ |
| 24 | 1346 | | | | 995 | | | | 1268 | | | |
| 25 | 1170 | | | | 1014 | | | | 1190 | | | ✓ |
| 26 | 1112 | | | | 995 | | | | 1190 | | | |
| 27 | 1053 | | | | 1112 | | | | 956 | | | |
| 28 | 1053 | | | | 1092 | | | | 1131 | | | |
| 29 | 1014 | | | | 1112 | | | | 1170 | | | |
| 30 | 1112 | | | | 1053 | | | | 1170 | | | |
| 31 | 1424 | | ✓ | | 1034 | | ✓ | | 1268 | ✓ | ✓ | ✓ |
| 32 | 1248 | | ✓ | | 1014 | | ✓ | | 1287 | | | ✓ |
| 33 | 1385 | | | | 1073 | | | | 1287 | | | ✓ |
| 34 | 1307 | | ✓ | | 995 | ✓ | ✓ | | 1209 | | ✓ | ✓ |
| 35 | 839 | | | | 1404 | | | | 995 | | | |
| 36 | 1092 | | | | 1053 | | | | 1034 | | | |
| 37 | 1053 | | ✓ | | 1053 | | ✓ | | 1014 | | ✓ | ✓ |
| TOTAL | | 2 | 12 | 16 | | 3 | 11 | 19 | | 3 | 14 | 19 |